Exchanges

- Selected Research Papers -

The CORC/ARCHES Observing System for Weddell Sea Deep and Bottom Water Variability[1]

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The abyssal ocean is filled with cold, dense water that obtains it characteristics on the Antarctic continental shelf and by mixing while sinking along the slope. Recent estimates of water mass formation rates using CFC inventories suggest that a total of 8 Sv of Antarctic Bottom Water (AABW) are formed (Orsi et al., 1999). The Weddell Sea Gyre transports about 5 Sv of Deep and Bottom water and thus contributes as much as 50% to the formation of AABW (e.g. Gordon et al., 2001, Fahrbach et al., 1994; 1995; Meredith et al., 2001). Global steady state tracer budgets have yielded much larger southern hemispheric abyssal ventilation rates for waters below 1500m (Broecker et al., 1998; Peacock et al., 1999). However, Orsi et al. (2001) point out that part of the controversy can be explained by separately considering the layer below 2500m. Obviously we need to know more about the mean and equally importantly about the variability of AABW formation rates and processes. In what way is ventilation from the south responding to changes in the surface boundary conditions and might we expect rapid change with global consequences (Broecker et al., 1999).

Much of the global AABW production is feed by the Bottom Waters formed by mixing between warm circumpolar deep water and Shelf Waters around Antarctica. Streams of relatively low salinity Weddell Sea Deep Water with temperature between 0° and -0.7°C are found along the outer rim of the Weddell Sea with varying degree of oxygen saturation (Figure 1) (Gordon et al., 2001). Between 1989 and 1998 Fahrbach et al. (2001) deployed a current meter array east of Joinville Island which allowed for the first glimpse at interannual variability in temperature, thickness and transport of the WSBW formed in the Weddell gyre region. Starting in April 1999 we continued the time series at a down stream location south of the South Orkney Islands with a small mooring array (Figure 2). This location is easier to maintain since the sea ice covered season is shorter on average. Our program has two elements: A repeat hydrographic section across the northwestern Weddell gyre outflow including observations of trace elements (CFCs and Tritium/Helium) and an array of three moorings. Two of them are equipped with nominally two current meter, two TS recorder and several T recorder covering a 500m thick layer above the sea floor. The third mooring consists of a profiling CTD and current meter package which is capable of obtaining a 1000m long profile every other day.

Gordon et al. (2001) give a recent review of the hydrography of the region pointing out the two streams of bottom water found on both sides of the Endurance ridge. Here we present repeat hydrographic sections sections for five occupations and show the evolution of the temperature and CFC 11 distributions (Figure 2). We found warming of the Warm Deep Water (WDW) in the 200-500m layer of warmest temperature (Robertson et al., 2001). However, the temperature changes in the bottom waters are not as simple (Figure 2). In particular the 1999 survey showed a colder bottom water type. Was this just a short term event? Or was the whole seasons bottom water production characterised by a cooler variety? Figure 2 also shows two years of data from mooring M2 just south of the S. Orkney Islands. Indeed, we find cooler bottom waters throughout the season with warmer conditions returning just a few month prior to the February 2000 survey. The southern mooring M3 could not be recovered in 2001 due to an unusually strong ice cover. However, an even more dramatic warming was found during the first year. The cold water during 1999 was seen a year earlier in the AWI array upstream (stars in Figure 2, (Fahrbach et al., 2001)). The profiling mooring M1 saw warming throughout a layer from 200m to 1500m depth during the first season (not shown). In addition to the thermal profiles detailed information about the vertical current structure revealed a strong internal wave signal propagating energy upward into the water column (Figure 3).

The evolution of the theta/CFC relationship in the bottom water is different for the branch north of Endurance Ridge (M2) and the branch south of the ridge (M3) (Figure 4). North of the ridge the theta/CFC relationship is the same for 1997/1998 and 1999/2000 with a distinct increase in CFC concentration between 1998 and

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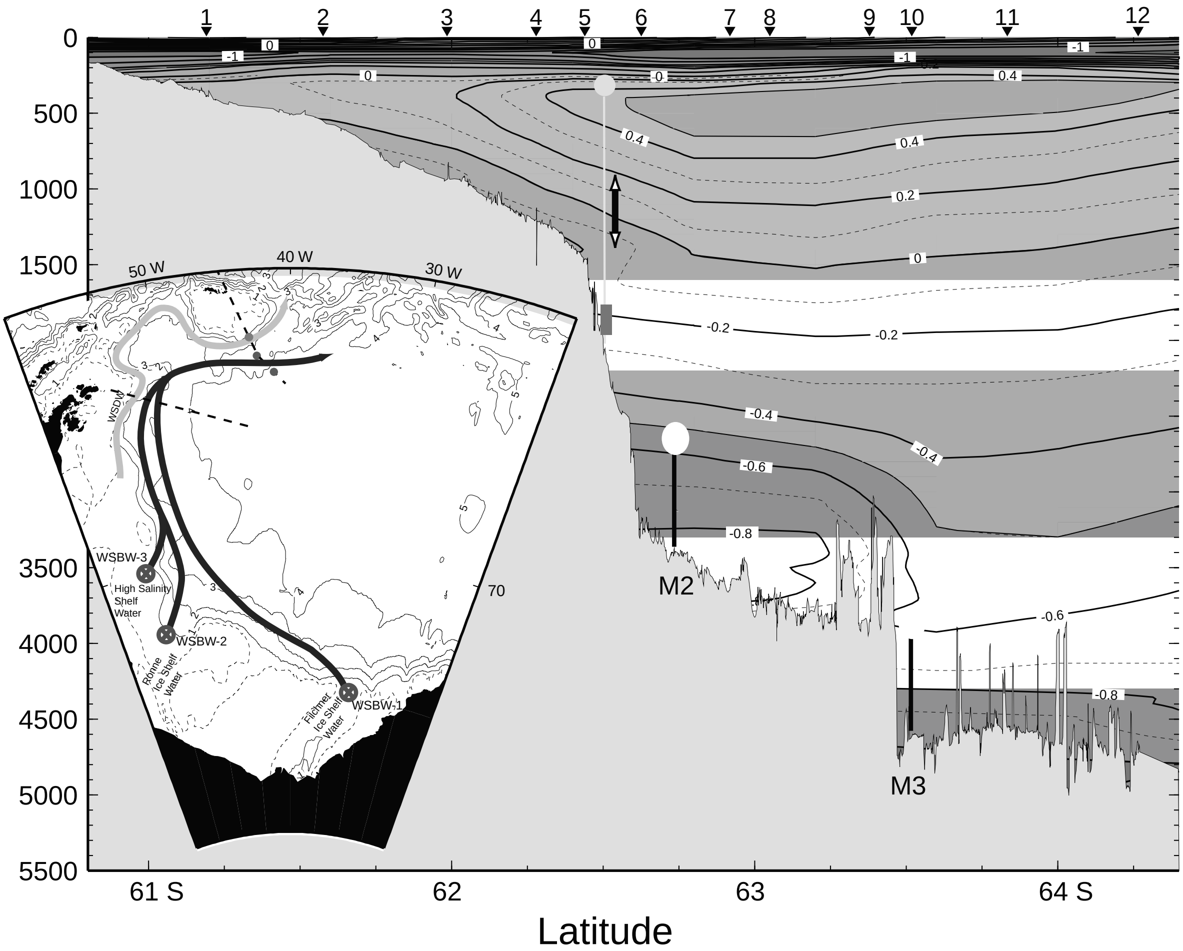

Fig. 1. Potential temperature section south of the South Orkney Islands with the location of the mooring array superimposed. Inset: Bathymetric map of the Weddel Sea Gyre indicating the position of several streams of newly formed Weddell Sea Bottom Water (Gordon et al. 2001) and the CORC/ARCHES repeat section and mooring array.

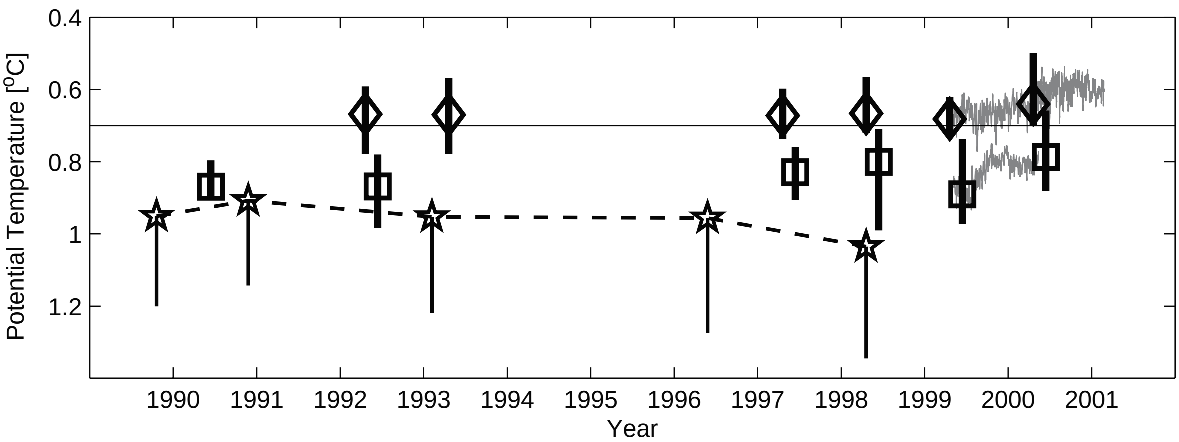

Fig. 2. Potential temperature time series as obtained from repeat hydrographic sections in the northwestern Weddell gyre. Diamonds denote the mean temperature between 2600 and 3200 m water depth near 62.5°S 43.5°W (near M2). Squares denote the mean temperature between 4000 and 4600 m water depth near 63.5°S 42.0°W (near M3). The bars covers the total range of observed temperatures. The thin gay lines represent the 40h low pass filtered temperatures averaged over all sensors at mooring M2 and M3 respectively. The stars are the plume mean temperatures from Fahrbach et al. (2001) at their upstream array location. The solid line connects the plume mean with the coldest temperature found during each survey.

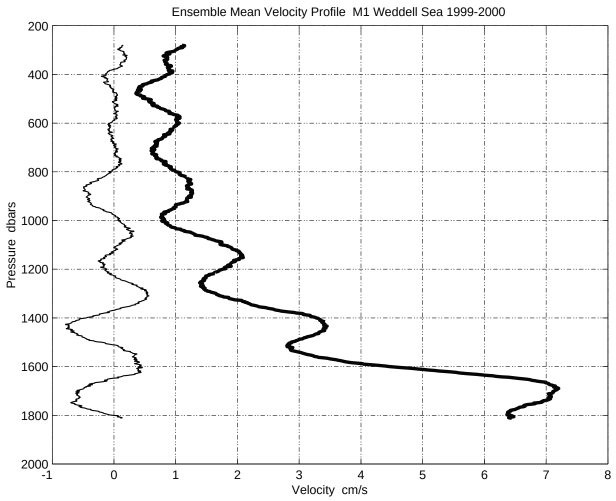

Fig. 3. Deployment mean velocity profile from the moored profiler. Thick line denotes along slope velocity and the thin line the across slope velocity component. It is not clear if the high vertical wave number signal is due to lee waves or due to the limited time sampling of a strong tidal signal.

1999. This may be the result of greater ventilation in the shelf regions during the formation of the 1999 and 2000 vintages or may be from the increase atmospheric CFC concentrations over the period when the water formed. South of the Endurance Ridge the CFC concentration with respect to temperature decreases between 1997 and 1998, increases between 1998 and 1999, and decreases between 1999 and 2000. Also the temperature of the bottom water warms between 1999 and 2000. These observations indicate variability in the air-sea interaction processes that form the shelf water before it flows off the shelf or variability in entrainment after it exits the shelf.

We plan and have partial funding to continue the observations for the CLIVAR decade to document changes in the Weddell Sea Bottom Water characteristics. We are interested to expand our array to include moored observations of sea-ice thickness and velocity and a moored water sampler for CFCs. The extended time series (Figure 2, 4) can then be compared to variability in the surface fluxes of buoyancy and momentum, sea ice cover and other changes in the environment such as mayor shifts in the ice shelf topography. They also provide bench marks for any model based study of climate variability in the region.

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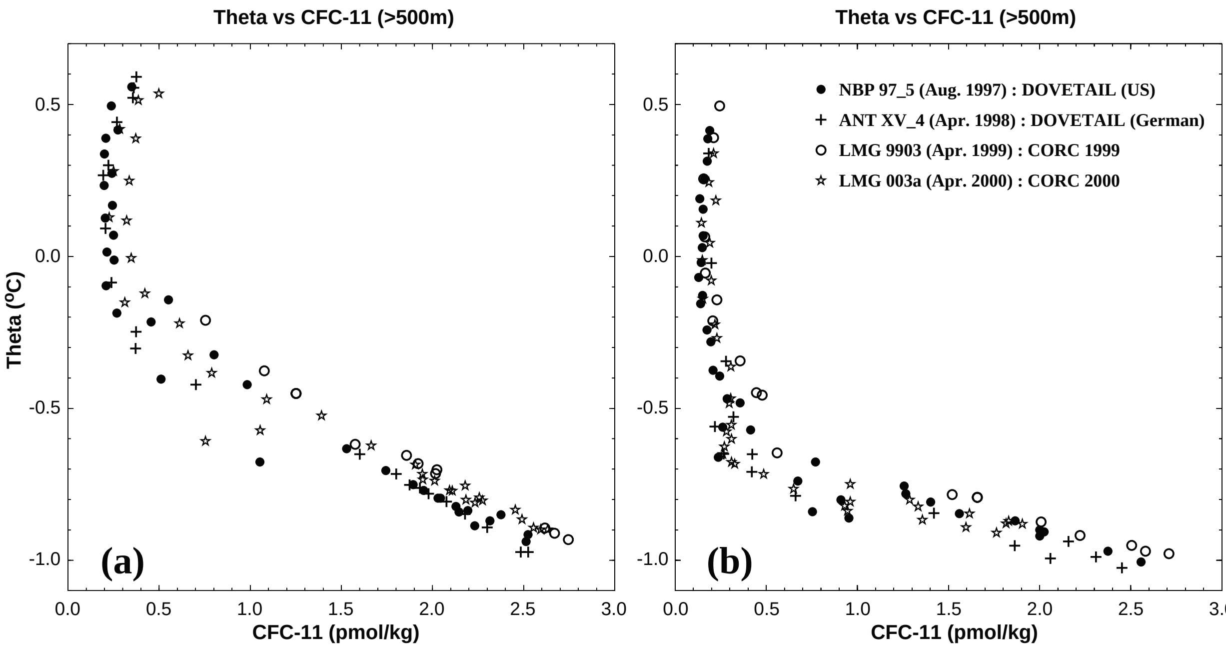

Fig. 4. Potential temperature verses CFC-11 for deep and bottom water (a) north and (b) south of Endurance Ridge south of the South Orkney Plateau for four different repeat hydrographic surveys.

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